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Complications of adenotonsillectomy for obstructive sleep apnea in school-aged children

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ABSTRACT

Introduction: Adenotonsillectomy is the treatment of choice for most children with obstructive sleep apnea syndrome, but can lead to complications. Current guidelines recommend that high-risk children be hospitalized after adenotonsillectomy, but it is unclear which otherwise-healthy children will develop post-operative complications. We hypothesized that polysomnographic parameters would predict post-operative complications in children who participated in the Childhood AdenoTonsillectomy (CHAT) study.
Methods: Children in the CHAT study aged 5–9 years with apnea hypopnea index 2–30/h or obstructive apnea index 1–20/h without comorbidities other than obesity/asthma underwent adenotonsillectomy. Associations between demographic variables and surgical complications were examined with Chi square and Fisher's exact tests. Polysomnographic parameters between subjects with/without complications were compared using Mann–Whitney tests.
Results: Of the 221 children (median apnea hypopnea index 4.7/h, range 1.2–27.7/h; 31% obese), 16 (7%) children experienced complications. 3 (1.4%) children had respiratory complications including pulmonary edema, hypoxemia and bronchospasm. Thirteen (5.9%) had non-respiratory complications, including dehydration (4.5%), hemorrhage (2.3%) and fever (0.5%). There were no statistically significant associations between demographic parameters (gender, race, and obesity) or polysomnographic parameters (apnea hypopnea index, % total sleep time with $SpO_2 < 92\%$, SpO_2 nadir, % sleep time with end-tidal $CO_2 > 50$ Torr) and complications.
Conclusions: This study showed a low risk of post-adenotonsillectomy complications in school-aged healthy children with obstructive apnea although many children met published criteria for admission due to obesity, or polysomnographic severity. In this specific population, none of the polysomnographic or demographic parameters predicted post-operative complications. Further research could identify the patients at greatest risk of post-operative complications.

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1. Introduction

Obstructive sleep apnea syndrome (OSAS) affects up to 4% of the pediatric population [1]. A wide range of adverse health outcomes has been associated with untreated OSAS, such as cardiopulmonary abnormalities [2,3] and failure to thrive [4,5]. Furthermore, there is growing evidence suggesting links between pediatric OSAS and behavioral problems, mood impairment, excessive daytime sleepiness, impaired school performance and poor quality of life [6,7].

Adenotonsillar hypertrophy is the most commonly recognized anatomic risk factor for pediatric OSAS [8] and therefore adenotonsillectomy (AT) continues to be the primary treatment [9]. AT is the second most common pediatric surgery under general anesthesia in the United States, with approximately 218,000 procedures performed annually in school age children [10]. Minor complications include pain, nausea, vomiting and dehydration [11]. However, more severe complications may occur, including hemorrhage, respiratory decompensation, velopharyngeal incompetence, subglottic stenosis, and rarely death [12]. There are a number of identified risk factors for post-operative complications, including age younger than 3 years, obesity, comorbid airway anomalies, Down syndrome and other genetic syndromes, craniofacial abnormalities and neuromuscular disease [13–18]. However, most of the studies that identified these risk factors were based on retrospective data [9] from heterogeneous populations, have often not included polysomnographic (PSG) documentation of OSAS, and have used different definitions of post-operative complications. The risks of AT in otherwise healthy, school-aged children with OSAS are unclear. In these otherwise healthy children, it has been assumed that OSAS severity primarily based on the apnea hypopnea index (AHI) or oxyhemoglobin saturation nadir is the major risk factor for post-operative complications [19–22].

The gold standard for the diagnosis of OSAS is overnight polysomnography [9] which also helps to quantify the severity of OSAS. However, there is no consensus as to the PSG parameters predictive of post-operative complications and hence, which patients would benefit from elective post-operative admission rather than outpatient surgery. According to the recent guidelines published by the American Academy of Pediatrics (AAP), patients with an apnea hypopnea index (AHI; number of obstructive apneas and hypopneas per hour of sleep) $\geq$24/h, oxyhemoglobin saturation (S_PO_2) nadir $<$80% or peak PCO_2 $\geq$60 mmHg should be hospitalized postoperatively [9]. In contrast, the recently published clinical practice guidelines from the American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS) recommend that children with an AHI $\geq$10/h or an S_PO_2 nadir $<$80% be admitted electively [8]. Both guidelines are based on evidence from retrospective studies or studies of heterogeneous populations and, therefore, not surprisingly, differ in their recommendations.

In summary, severe OSAS is considered a risk factor for post-operative risk after AT. This notion has justified the practice of hospitalizing many children for post-operative monitoring rather than conduct the procedure as an outpatient procedure. Many of these children are older with few if any comorbidities. The problem is magnified by the paucity of published data regarding the polysomnographic variables predictive of adverse respiratory and non-respiratory events post AT in relatively older (school-aged) and healthy children with obstructive sleep apnea. We therefore sought to determine whether demographic, anthropometric or PSG measures would identify children with elevated post-operative risk in a homogenous study cohort of school-aged children with PSG-proven OSAS without significant medical comorbidities other than obesity.

2. Methods

2.1. Study design and population

This is an ancillary analysis of postsurgical complications from participants in the early adenotonsillectomy arm of the Childhood Adenotonsillectomy (CHAT) study [6,23]. CHAT was a single-blind, randomized controlled trial at six academic centers designed to evaluate the efficacy of early AT versus Watchful Waiting with Supportive Care (WWSC) in children with OSAS. The hypothesis of the CHAT study was that in children with OSAS without prolonged desaturation, early AT (performed within 4 weeks after randomization), as compared with WWSC would result in improved polysomnographic, cognitive, behavioral, and health outcomes within a 7 month period. The methodology of the CHAT study has been described in detail separately [23] but is also briefly reported below. Informed consent was obtained by the parents/guardians and assent from the child where appropriate, and the study received approval by the Institutional Review Boards of all participating sites. In addition, all serious and unexpected adverse events of the study were tabulated for review by a Data Safety Monitoring Board. All children/caregivers received information on sleep hygiene using standardized educational materials that identified the need for regular sleep routines, age-appropriate sleep duration, and avoidance of caffeine prior to bedtime and were provided information on healthy lifestyle (nutrition, exercise). Children also were provided with saline nasal spray to be used nightly. Children had monthly telephone calls/visits to assess their state of health. Children randomized to WWSC were scheduled for reevaluation for surgery by an otolaryngologist after the 7 month observation period, and received treatment as clinically indicated. The primary outcome was changed in the Attention/Executive Functioning Domain score from the Developmental NEuroPSYchological Assessment (NEPSY A/E). The summaries of results addressing the primary and secondary key outcomes of this study are published separately [6].

The CHAT cohort included children aged 5–9 years who had OSAS without prolonged oxyhemoglobin desaturation (AHI 2–30/h and S_PO_2 $<$90% for no longer than 2% of total sleep time [TST]) and did not have any other severe health problems. OSAS was defined as an AHI $\geq$2/h or an obstructive apnea index $\geq$1/h. Exclusion criteria included severe obesity with a body mass index z-score $\geq$ 3, craniofacial anomalies or any major systemic condition.

Polysomnography was performed and scored at a central Sleep Reading Center according to the American Academy of Sleep Medicine pediatric standards [24]. AT was performed using standard surgical techniques (cold dissection, monopolar electrocautery, coblation or micro-debrider, with variation according to surgeon preference) after viewing a mandatory training video which summarized the surgical protocol and after reviewing the CHAT study manual of procedures. In addition there was ongoing oversight by a surgical quality assurance committee. To ensure uniformity across participating sites, intraoperative photographs were obtained on every 10th consecutive patient at each site and reviewed for adequacy of lymphoid tissue removal by the surgical core director. In most cases, AT was an outpatient procedure (i.e., no overnight hospitalization). If PSG showed an AHI was $>$20/h, or the S_PO_2 was $<$92% for $>$2% of TST, then the clinical site was alerted so that appropriate post-operative management would be considered. Each center followed their own practices regarding elective post-operative admissions based on criteria such as severity of OSAS on PSG, obesity or surgeon's preference.

For each admission, a member of the research team at each site reviewed their medical records for further information regarding the presence or absence of complications and interventions during

their hospital stay. In order to capture any complications within 4 weeks post-adenotonsillectomy, research coordinators also telephoned the families approximately 4 weeks following surgery, using a templated case report interview form.

Outcomes that were evaluated included hypoxemia (defined as a S_PO_2 <90 and requiring intervention); laryngospasm; bronchospasm; interventions such as supplemental oxygen, nasopharyngeal airway use, continuous positive airway pressure, bi-level positive airway pressure, prolonged postoperative endotracheal intubation or re-intubation; airway hemorrhage; poor oral intake requiring intravenous fluid administration; dehydration; fever; emergency department visits; and planned or unplanned admissions.

2.2. Statistical analysis

Statistical analyses were conducted in SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.; 2011 with two sided tests and a p value of <0.05 as the criterion for statistical significance.

The following polysomnographic parameters were evaluated as predictors of post-operative complications: AHI, percentage of TST with S_PO_2 < 90% and <92%, S_PO_2 nadir, peak end-tidal CO_2 and percentage of TST with end-tidal CO_2 > 50 mmHg. The demographic parameters evaluated as predictors of post-operative complications were age, gender, race and obesity (based on BMI z-score of ≥1.65 which is equivalent to BMI > 95th percentile). Dichotomous outcome variables were created based on occurrence of particular complications as follows: emergency department (ED) evaluation; hospital admission; and respiratory, non-respiratory (dehydration, fever and hemorrhage) and total complications.

Parameters are presented as means and standard deviations for normally distributed continuous variables and medians and minimum and maximum values for variables with skewed distributions. Fisher's exact tests were used to examine associations between categorical demographic variables and occurrence of complications. The Mann–Whitney test was used to compare polysomnographic parameters between subjects with and without complications. Multiple linear regression models and point-biserial correlations were used to explore the association between PSG variables and post-operative complications. Demographic parameters such as age, race and BMI z-score were included in the model as additional covariates. Chi-square tests were used to examine associations with the presence of any complication between subjects whose polysomnographic findings were in the most severe quintile for AHI or gas exchange abnormalities compared to the remainder of the study group.

3. Results

A total of 464 children were recruited to CHAT, of whom 206 were randomized to AT. In addition, 15 subjects randomized to watchful waiting crossed over to AT due to either worsening of their medical condition or parental preference, and were included in this study. Thus, all 221 children who underwent surgery were evaluated in this analysis. Demographic and PSG data are shown in Tables 1 and 2. Forty-six (21%) subjects met AAO-HNS criteria for admission, and 33 (15%) met AAP criteria (Table 3).

3.1. Total complications

Of the 221 subjects, 16 (7%) were identified with post-operative complications. Three (1.4%) had respiratory complications (see below). Thirteen (5.9%) had non-respiratory complications, including dehydration requiring medical evaluation and/or treatment (4.5%), hemorrhage (2.3%) and fever (0.5%). Details of post-operative complications are shown in Fig. 1.

3.2. Immediate post-operative complications

Six children (2.7%) had complications in the immediate post-operative period: 3 with respiratory complications (of whom 2 were admitted) and 3 with non-respiratory complications (all of whom were admitted) resulting in a total of 5 unplanned admissions. Of the group with respiratory complications, one child with obesity and moderate OSAS (AHI 9.7/h, S_PO_2 nadir 84%) had pulmonary edema associated with respiratory distress and desaturation, which resolved with the use of a nasopharyngeal airway and loop diuretics, extending the hospital stay by one day. Another child developed hypoxemia in the post anesthesia care unit, and was therefore placed on supplemental oxygen and admitted for overnight observation. The child's PSG showed mild obstructive sleep apnea (AHI of 3.3/h, S_PO_2 nadir 93%). The child had no other comorbidities. A third child with mild OSAS (AHI 3.9/h, S_PO_2 nadir 89%) without a history of asthma developed severe bronchospasm requiring re-intubation in the post-anesthesia care unit. The child recovered and was discharged on the same day. None of these 3 children with respiratory complications met either AAO-HNS or AAP admission criteria.

Three children had non-respiratory complications leading to admission; all 3 required intravenous fluid administration for dehydration due to either decreased oral intake only (in two children) or due to a combination of decreased oral intake and emesis in one child. One of these children had an AHI of 11.4/h and therefore met the AAO-HNS admissions criteria.

3.3. Elective admissions

Twenty-three (10.4%) children were electively admitted from 3 institutions, one of whom had a PSG that met criteria for pre-operative alerts to the site (i.e., showing more than 2% of total sleep time at an oxygen saturation <92%). Per institutional policy, all admitted patients at two of the institutions routinely received intravenous fluids (N = 15). At the 3rd institution, intravenous fluids were not administered unless needed for decreased oral intake. All patients had an uneventful hospital course and were discharged the following day.

Table 1
Demographic data of the study population based on the presence or absence of post-operative complications.

Demographics	Group without complications N = 205	Group with complications N = 16	p-Value
Age (years)	6.6 ± 1.4	6.5 ± 1.5	0.82*
Gender (N, %)			1.00**
Males	96 (46.8)	7 (43.8)	
Females	109 (53.2)	9 (56.3)	
Race (N, %)			1.00**
African American	109 (53.2)	9 (56.3)	
Non-African American	96 (46.8)	7 (43.8)	
BMI z-score	0.84 ± 1.33	0.78 ± 1.48	0.86*
Obesity (N, %)			1.00**
Obese	64 (31.2)	5 (31.2)	
Non obese	141(68.8)	11(68.8)	
Failure to thrive (N, %)			0.41**
Failure to thrive	6 (2.9)	1 (6.3)	
No failure to thrive	199 (97.1)	15 (93.8)	

Data are shown as mean ± SD or N (%).
There were no statistically significant differences between the two groups.
* p-Value from two-group t-test.
** p-Value from Fisher's exact test.

Table 2
Baseline polysomnographic data of the study population based on the presence or absence of post-operative complications.

Baseline PSG data	Group without complications	Group with complications	*p*-Value*
Arousal index (N/h)	8.2 (2.4, 20.6)	7.7 (4.8, 9.8)	0.21
Apnea hypopnea Index (N/h)	4.7 (1.2, 27.7)	5.7 (1.5, 19.1)	0.65
S_PO_2 nadir (%)	90 (61, 97)	89 (70, 94)	0.34
Time with $S_PO_2 < 92\%$ (% total sleep time)	0.1 (0.0, 5.6)	0.1 (0.0, 3.6)	0.49
Peak end-tidal CO_2 (mmHg)**	55.1 (44.4, 68.4)	54.0 (49.8, 57.3)	0.31
Time with end-tidal $CO_2 > 50$ mmHg (% total sleep time)**	1.7 (0.0, 97.0)	1.0 (0.0, 21.6)	0.44

Data shown as median (minimum, maximum).
* *p*-Value from Mann–Whitney test. There were no statistical significant differences between the two groups.
** *N* = 184.

Table 3
Clinical practice guidelines admission criteria and presence of complications.

	AAO-HNS criterion	AAP and AAO-HNS criterion	AAP criterion	AAP criterion		
	AHI ≥ 10/h	$SpO_2 < 80\%$ only	AHI ≥ 24/h	$CO_2 \geq 60$ mmHg[a]	Meets any AAO-HNS criteria	Meets any AAP criteria
Subjects meeting admission criteria (*N*)	43	8	7	22	46	33
Subjects meeting criteria who had complications (*N*)	3	1[b]	0	0	3	1

Note that some subjects met multiple criteria.
AAO-HNS, American Academy of Otolaryngology-Head and Neck Surgery; AAP, American Academy of Pediatrics; AHI, apnea hypopnea index; SpO_2, arterial oxygen saturation.
[a] *N* = 184.
[b] This subject also had an AHI > 10/h.

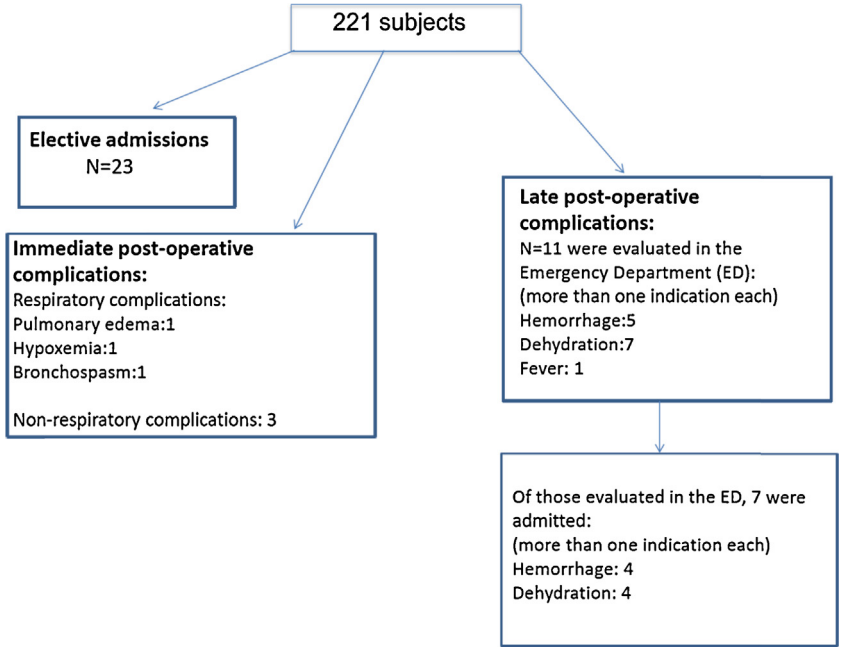

Fig. 1. Details of post-operative complications are shown.

3.4. Late post-operative complications

Eleven children had late complications (within 4 weeks post-adenotonsillectomy) requiring emergency department evaluation following discharge. Emergency department evaluations were sometimes for more than one indication, and included 5 cases of hemorrhage, 7 cases of dehydration and 1 case of fever. Of these patients, 7 were admitted (3 cases of hemorrhage, 3 cases of dehydration and 1 case with both hemorrhage and dehydration). One child (AHI 19.1/h, nadir SpO_2 70%) seen in the emergency department for fever and dehydration but not admitted met both AAO-HNS and AAP admissions criteria, and another child (AHI 18.5/h) admitted for dehydration met AAO-HNS criteria.

3.5. Predictors of complications

There were no statistically significant associations between demographic variables (gender, race or obesity) or PSG parameters and the presence of either respiratory or non-respiratory

Table 4
Baseline polysomnographic parameters and their rank-biserial correlation with post-operative complications.

Baseline PSG data	Respiratory complications			Non-respiratory complications		
	Coefficient	*N*	*p*-Value	Coefficient	*N*	*p*-Value
Apnea Hypopnea Index (N/h)	0.003	221	0.82	0.014	221	0.71
S_PO_2 nadir (%)	−0.002	221	0.90	−0.035	221	0.32
Time with $S_PO_2 < 92\%$ (% total sleep time)	0.008	221	0.71	0.023	221	0.56
Peak end-tidal CO_2 (mmHg)	0.003	184	0.81	−0.044	184	0.082
Time with end-tidal $CO_2 > 50$ mmHg (% total sleep time)	0.005	184	0.61	−0.036	184	0.28

Data shown as rank-biserial correlation coefficient, *N* and *p* value.

complications (Table 4). In addition, there were no statistically significant associations between the above variables and the presence of a late complication requiring evaluation in the emergency department or the need for admission.

There was no increased rate of complications in children with the highest AHI quintile or the worse quintile of gas exchange abnormalities.

4. Discussion

In summary, this prospective study of school-aged, otherwise-healthy children with OSAS found a low incidence of post-operative complications, and no significant demographic or PSG predictors of either respiratory or non-respiratory complications.

This study found that 7% of children had post-operative complications. More specifically, 2.3% patients required an unplanned admission due to complications in the immediate post-operative period and 3.2% required admission due to late post-operative complications. This is similar to the literature, in which about 1.3% of patients experience delayed discharge during the initial hospital stay, and up to 3.9% have secondary complications requiring admission [8]. The incidence of non-respiratory complications (dehydration 4.5%, hemorrhage 2.3% and fever 0.5%) was also similar to that reported from other studies [25]. However, the rate of post-operative respiratory complications was lower (1.4%) than the range of 5–23% reported in the literature [26–28]. This difference may be explained by the fact that the prior literature mostly involved retrospective studies with heterogeneous samples with respect to their use of PSG to diagnose OSAS, PSG methodology, composition of the patient populations (especially age and presence of other comorbidities) and variable definitions of respiratory complications (some describing minor complications such as desaturation and other include complications requiring intervention such as non-invasive ventilation or intubation). Indeed, most published studies included younger children, who likely are higher risk than the school-aged children in the current study. Another factor may have been that children with prolonged desaturation were excluded from the current study, although children with an AHI as high as 30/h were included.

There were no statistically significant correlations between PSG parameters and the presence of respiratory complications (Table 4). Since children with the most severe findings were excluded from the CHAT study, we cannot exclude the possibility that inclusion of extremely abnormal PSG values would have improved prediction of post-operative complications. However, the AHI eligibility threshold was quite high at 30, and thus our findings indicate that over a relatively wide range of OSAS severity in children 5–9 years of age, the PSG has limited value in predicting post-operative complications. This observation is in contrast to findings from other studies which have shown that the AHI and the S_PO_2 nadir correlate with the presence of respiratory post-operative complications [19,20,29]. Children in the current study were older than those in earlier studies and did not have additional comorbidities, which may account for some of these differences. Sixty children met either the AAO-HNS or AAP admissions criteria; of those only 3 (5%) had post-operative complications, i.e., the vast majority of children meeting guideline admission criteria did not have complications (Table 3). Of the 161 children who did not meet either of the guidelines admission criteria, 13 (8%) had post-operative complications.

In this study cohort, age and other demographic factors were not predictors of post-operative complications. Although almost a third of the subjects were obese, obesity was not found to be a risk factor. This differs from other reports such as the study by Spector et al. which included 14 morbidly obese patients treated with AT [30]. Of those, 1 patient needed intubation and 2 patients were treated with bi-level positive airway pressures (BPAP). Another retrospective review of 26 morbidly obese patients found that 12 (45%) required respiratory intervention, including 1 requiring intubation and 1 requiring BPAP [22]. Reasons for this discrepancy between study results may be that obesity is only a risk factor when it interacts with other comorbidities, or that obesity is only a risk factor in children with extreme obesity (as children with a BMI > 3 *z*-scores were excluded from this study).

Strengths of this present study include the well-characterized population and the prospective follow-up with formal review of adverse events. Limitations include the relatively small number of children with complications, which precluded identification of any but large associations. In addition, the study excluded children with very severe apnea (AHI > 30/h) or with prolonged desaturation (although children with saturation nadirs as low as 61% were included). However, the study did include children with an AHI within the range mentioned in the published guidelines regarding post-operative admission by both the AAP [9] and the AAO-HNS [8].

Of the patients who were electively admitted and observed overnight, it is possible that interventions such as intravenous fluids and pain medication administration may have influenced patient outcomes. In addition, children who were admitted overnight may have benefited from interventions such as suctioning or repositioning, which may have altered their outcome regarding respiratory complications.

In summary, this prospective study has shown a relatively low risk of post-adenotonsillectomy complications, in particular, in the immediate post-operative period, in school-aged generally healthy children with polysomnographically proven OSAS, many of whom meet clinical guideline criteria for admission due to obesity or severe OSAS. Neither demographic factors nor PSG values predicted post-operative complications. Further research is needed on the cost-effectiveness of PSG and admission guidelines on health and safety outcomes in children undergoing AT.

Authors' contributions

All authors did the data analysis, data interpretation and critical review of the manuscript. Dr. Paul Gallagher did the statistical analysis. Dr. Raouf Amin, Dr. Carole Marcus, Dr. Carol Rosen and

Dr. Susan Redline did the funding of the study. Dr. Sofia Konstantinopoulou and Dr. Carole Marcus did the conception and the drafting of this manuscript.

Author's conflicts of interest

Dr. Marcus reports receiving a loan of research equipment from Philips Respironics and Ventus Medical. Dr. Redline received a grant from ResMed Foundation and ResMed Inc and equipment for use in research from ResMed Inc and Philips Respironics. Dr. Chervin reports serving as a board member for the American Academy of Sleep Medicine, American Sleep Medicine Foundation, American Board of Sleep Medicine, Association Professional Sleep Societies, International Pediatric Sleep Association, and Sweet Dreamzzz; receiving consulting fees from Procter & Gamble, MC3, and Zansors; having patents, patents pending, and copyrighted material, owned by his institution, for assessment and treatment of sleep disorders; receiving royalties from Up-to-date and Cambridge University Press; and receiving gifts to his institution for educational purposes from Philips Respironics and Fisher and Paykel. Dr. Shalini Paruthi has no conflicts of interest but she reports royalties from Up-to-date for writing on obstructive sleep apnea. No other potential conflicts of interest relevant to this article were reported.

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